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# Development and Tracking in Fitness Components: Leuven Longitudinal Study on Lifestyle, Fitness and Health

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In the Leuven Growth Study of Belgian Boys the growth and physical performance of Belgian boys followed longitudinally between 12 and 19 years were studied. Subsequently, a subsample (n = 240) of Flemish-speaking males were reexamined at 30 and 35 years. A first question relates to the individual growth patterns in a variety of physical fitness characteristics. The three strength tests (static, functional, explosive) show curves that are qualitatively similar to those for height and weight. Their adolescent spurts occur after the height spurt. Flexibility and the two speed tests appear to reach maximum velocities prior to the height and weight spurts. Longitudinal principal component analysis was applied to the study of growth patterns of several somatic and motor characteristics. The results for height show three components sufficient to provide an adequate representation of the original information. The first component characterizes the general position of an individual growth curve. Components 2 and 3 reflect fluctuation in percentile level during the age period studied and can be conceived as indices of stability and are related to age at peak height velocity (APHV) and peak height velocity (PHV), respectively. Relationships between somatic characteristics, physical performance, and APHV have been studied in a sample of 173 Flemish boys, measured yearly between  $\pm 13$  and  $\pm 18$  years and again as adults at 30 years of age. The sample was divided into three contrasting maturity categories based on the APHV. There are consistent differences among boys of contrasting maturity status during adolescence in body weight, skeletal lengths and breadths, circumferences, and skinfolds on the trunk. There are no differences in skinfolds on the extremities. None of the differences in somatic dimensions and ratios among the three contrasting maturity groups are significant at 30 years of age except those for subscapular skinfold and the trunk/extremity skinfold ratio. During adolescence, speed of

limb movement, explosive strength and static strength are negatively related to APHV; thus, early maturers performed better than late maturers. However, between late adolescence and adulthood (30 years), the late maturers not only caught up to the early maturers, but there were significant differences for explosive strength and functional strength in favor of late maturers. Finally, age-specific tracking, using inter-age correlations, of adult health- and performance-related fitness scores were investigated. In addition, the independent contribution of adolescent physical characteristics to the explanation of adult fitness scores was also studied. Tracking between age 13 and age 30 years was moderately high (46% of variance explained) for flexibility, low to moderate (between 19% and 27% of variance explained) for the other fitness parameters and low for pulse recovery and static strength (7% to 11% of variance explained). Between age 18 and age 30 years the tracking was high for flexibility, moderately high for explosive and static strength, and moderate for the other fitness parameters except for pulse recovery. The amount of variance of adult fitness levels explained increased significantly when other characteristics observed during adolescence entered the regressions or discriminant functions.

**Key words:** Growth, biological maturation, physical performance, longitudinal, adolescence, tracking

## Introduction

At the initiation of the Leuven Growth Study of Belgian Boys (18) little information was available concerning the individual growth patterns in a variety of fitness components, which is clearly demonstrated in an overview of multidisciplinary longitudinal growth studies (12). This lack of information together with the lack of well-documented growth and fitness characteristics of the Belgian population has led to the initiation of the Leuven Growth Study of Belgian Boys (18). The Center for Physical Development Research initiated a pilot study in January 1968 to select the most appropriate tests and measurements for physical fitness appraisal in a nationwide sample. Later in 1968 and continuing through 1974, a nationwide combined cross-sectional and longitudinal study was carried out and included more than 21,000 observations on 8,963 boys 12 through 20 years of age. Observations for each boy included a physical fitness test battery, anthropometric dimensions, somatotype, assessment of skeletal maturity, sports practice, and



sociocultural characteristics of the family. A description of the project and reference data for all tests and measurements were published by Ostyn et al. (18). Of interest is to note that the selection of fitness tests was based on a comprehensive investigation of the reliability and construct validity of a wide variety of fitness tests examined in the age range 12 through 20 years of age (21). The fitness components identified in this study and the tests selected served as the basis for the Moper test battery later on applied in the Amsterdam Growth and Health Study (11) and the Eurofit test battery (1).

The original growth study was later extended so that a subsample of about 175 Flemish-speaking subjects was included who have been reexamined at the age of 30, 35 and 40 years in 1986, 1991 and 1996, respectively.

In the present report a selection of the main findings, based on pure longitudinal data, will be documented. First, individual growth patterns of physical fitness components aligned on age at peak height velocity (APHV) will be discussed. Furthermore, longitudinal principal component analyses were used to further elucidate the individual growth characteristics. Second, somatic and fitness characteristics of contrasting maturity groups classified according to their APHV and followed until adulthood (30 years) will be highlighted and finally tracking in fitness components from adolescence into adulthood will be analyzed.

## Materials and Methods

### *Design and sample*

The Leuven Growth Study of Belgian Boys was designed to provide information about the status of physical fitness in the Belgian population and to collect information on the individual evolution and patterns of development of somatic and fitness characteristics. Moreover, it was planned to contrast fitness levels according to maturity status, sports practice and sociocultural characteristics of the family. With these objectives in mind it was decided to test about 4000 subjects each year and to conduct the cross-sectional and longitudinal study at the same time. Such a design was only possible when the sample could be based on the school population. Given the combined cross-sectional and longitudinal nature of the study, boys were examined at yearly intervals during the second school term (January to April). This implies that the age distribution covered exactly 1 year which has advantages even in a longitudinal design.

A multistage cluster sampling procedure was chosen considering the need for an adequate sampling frame. In the first stage, a proportionate stratified sample with schools as the primary sampling unit was selected. The strata were: language group (Flemish or French), type of schooling (vocational schooling or humanities), school body (private, i.e., Roman Catholic, or state schools), geographical distribution of the school population within and over the nine Belgian Provinces. The first sampling stage resulted in the selection of 59 schools. In the second stage of the sampling, entire classes were randomly selected from one grade of secondary school starting with the first grade in 1968, the second grade in 1969, and finally the sixth grade in 1974. The same schools were visited each year which made it possible for boys previously enrolled in the study to be

reselected in the following years. This combined cross-sectional and longitudinal design is very similar to the mixed or multiple longitudinal design which was indicated as the most efficient design for a developmental study (20, 24).

It can be seen that four birth cohorts were examined at six measuring periods, with 5 years of overlapping intervals. Moreover, many boys were studied over shorter intervals and 3474 boys were only measured once. From Table 1 it can be seen that from the original sample of 4278 boys observed in 1968, when they were in the first grade, only 588 were followed throughout the 6 years. Although considerable dropout was present given the design of the study it has been demonstrated that this dropout was not selective (18).

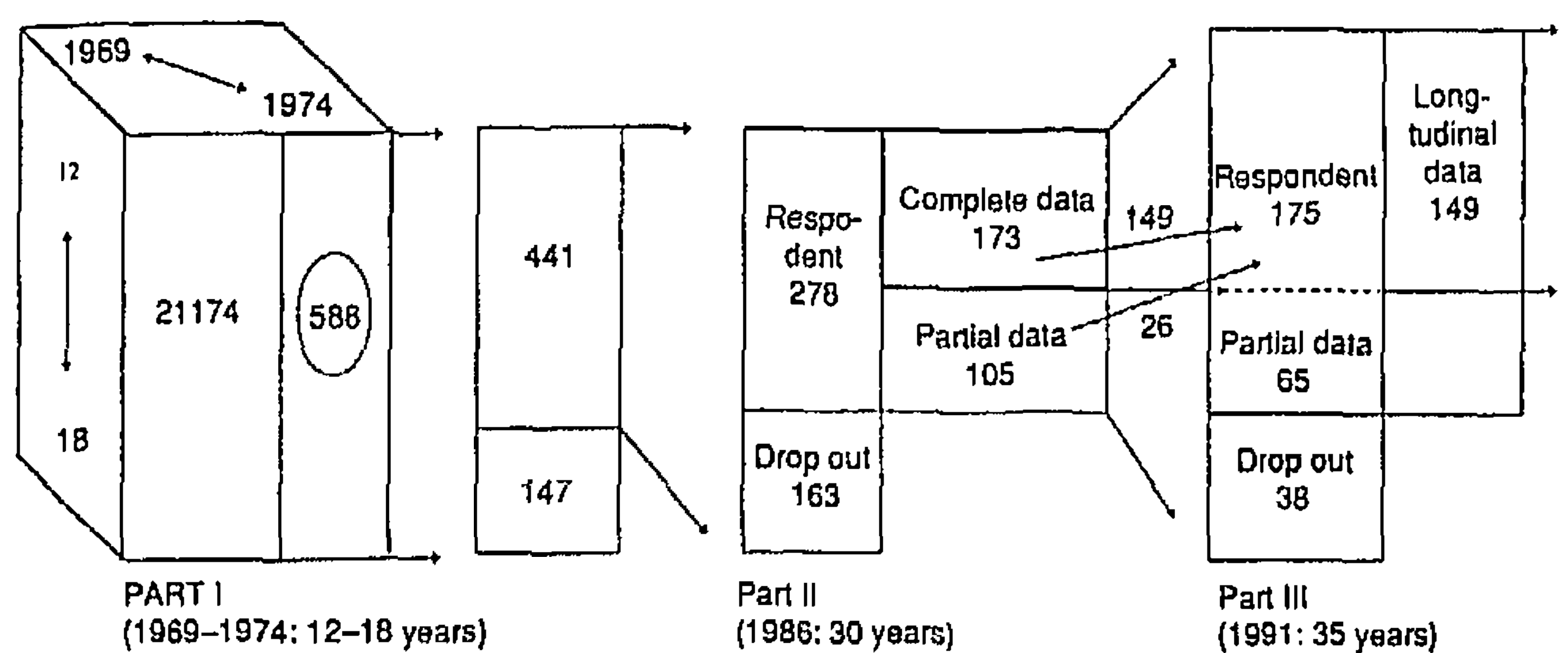
In 1986 the majority of the subjects who were followed over 6 years turned 30 years old and it was decided to extend the growth study in what is now called the Leuven Longitudinal Study of Lifestyle, Fitness, and Health. Of the 588 boys followed during their adolescent period, 441 were Flemish speaking and were considered for further enrollment in the follow-up. In 1986, 278 took part in the second part of the follow-up, and for 173 subjects longitudinal data are available from about 13 years to 30 years (Fig. 1). In the third part of the follow-up, in 1991, subjects were reexamined at the age of 35 and complete longitudinal data covering the whole period were collected for 149 male subjects. At present (September 1, 1996), 90 subjects aged 40 years already took part in the fourth part of the follow-up.

### *Tests and measurements*

From the initiation of the Leuven Growth Study of Belgian Boys the physical Fitness concept was operationalized in a broad sense including a test battery measuring a wide variety of performance characteristics, which were later identified as performance and health-related fitness components, and a behavior component, i.e., physical activity as measured by sport activities in organized and nonorganized settings. Considering that boys were studied during the growth period, somatic characteristics, and biological maturation were also examined as well as sociocultural characteristics of the family. As previously mentioned the selection of tests and measurements was based on the results of a pilot study on more than 750 secondary schoolboys in which the test-retest reliability of all fitness tests and anthropometric dimensions were investigated

**Table 1** Number of boys enrolled in the Leuven Growth Study of Belgian secondary schoolboys (18).

Measuring period	Number of examinations					
	1	2	3	4	5	6
1969	4278					
1970	1404	2921				
1971	1287	832	1863			
1972	1033	727	529	1177		
1973	629	604	379	366	783	
1974	332	442	482	239	280	588
Total	8963	5526	3253	1782	1063	588
						21115



**Fig. 1** Schematic representation of the different parts of the Leuven Longitudinal Study on Lifestyle, Fitness and Health (part IV, not indicated in the figure, is presently being conducted and involves male subjects 40 years of age).

and the fitness components identifiable in this age range were extracted from age-specific factor analyses (21). A detailed description of the tests and the anthropometric dimensions are given in Ostyn et al. (18). Anthropometric dimensions included four lengths, body mass, four widths, five circumferences and four skinfolds. Each year skeletal age was assessed, by the same assessor, using the Tanner-Whitehouse technique (22, 23). Furthermore, anthroposcopic and anthropometric somatotype estimations were made. Sports practice in private or school sport clubs but also in nonorganized contexts (with family, with friends or alone) was recorded by written questionnaires verified in oral interviews. Furthermore, a variety of family characteristics was collected in order to study the associations with fitness and somatic characteristics.

### Statistical analyses

A first question refers to the individual growth characteristics of fitness components aligned on APHV. Since it is difficult to apply structured or nonstructured growth models to a variety of performance measurements, covering a limited age range (six measurements per subject), and a moderate percentage of boys already reached the adult level, it was decided to estimate half-year velocities using nonsmoothed polynomials. Velocities at even time points were calculated assuming that the growth around this time point may be best described by a second-degree polynomial. Velocities at odd time points were calculated assuming that the growth curve around this time point was best described by a third-degree polynomial. More details about the calculations and formulas used and about the longitudinal data cleaning that preceded all calculations are given by Beunen et al. (7). Also a procedure was developed to estimate accurately the age at peak height velocity. Depending on the shape of the velocity curve around the interval with the maximum increment the age of the spurt was assigned to the midpoint of that interval when the velocity curve was symmetric or to the start or endpoint of that interval when the velocity curve was not symmetric. Individual velocity curves for the fitness components were calculated, for each subject aligned on his individual APHV, whereafter mean constant velocity curves were constructed for each fitness component aligned on APHV.

An alternative method of fitting functions to individual growth series is the longitudinal principal component analysis (8-10, 13, 14). This statistical technique can generally be employed since it does not assume any particular pattern of change with

age. As with standard principal component analysis, the objective is to simplify the original data by summarizing the majority of variation in each individual's serial observations in fewer than the original number of variables. The individual growth data are partitioned in a set of principal component functions. The principal variables are constant over time, but the component scores are specific for each individual and determine the weighting of the component functions in representing the particular growth series of each subject. This technique was used to identify the development characteristics in the fitness components. For each analysis a 6\*6 correlation matrix and a 6\*6 raw cross-products matrix was used as the starting point, using the princomp procedure of the SAS system (19). As in nonstructural growth models, there is no inherent biological meaning for the component functions. Any interpretation of the functions relies on a posteriori verification. A first verification was achieved by plotting the corresponding component functions as a function of time. The contributions of the loadings to the individual growth series could be checked and they provide an indication of the trends over time. A second verification was to present the growth patterns of individuals with extreme scores on the components, and a third source of information was a correlation analysis with parameters of the growth curves derived from the previous analysis. A more detailed description of these analyses is reported by Lefevre et al. (14).

A second question deals with maturity-associated variation in somatic dimensions and fitness characteristics. Although a number of studies report age-specific associations between indicators of biological maturation and performance characteristics, very little is known about the effect of early, average, or late maturation on adult performance characteristics (5). Furthermore, the studies looking at these associations in somatic dimensions are all limited in that they consider observations at 18 to 20 years as adult values (17). Given the nature of this follow-up study it was possible to contrast biological maturity groups based on APHV and study the somatic and performance characteristics from 13 through 30 years. APHV was estimated for 149 boys and the sample was then divided into three contrasting maturity categories based on APHV: early (APHV < 13.37 years), average (APHV between 13.85 and 14.80 years), and late (APHV > 15.27 years) maturers. Using ANOVA for repeated measures and one-way ANOVA (GLM procedure) (19) differences, in 18 somatic dimensions, five ratios of body proportions and subcutaneous fat distribution, and seven fitness tests among the three maturity groups were tested from 13-18 years and at 30 years of age (6, 15).

A final question concerns tracking in fitness characteristics. Tracking refers to the maintenance of the relative position in a group over time. Most often autocorrelations or interage correlations covering various age periods and time intervals are used as a tracking index. Autocorrelations were calculated for fitness scores at each age between 13 and 18 years and the fitness scores at 30 and 35 years. Furthermore, to verify whether adolescent characteristics contributed to the explanation of variance in adult fitness levels, stepwise multiple regressions were carried out for each of the fitness components at age 30 years as the dependent variables and somatic dimensions, fitness levels, skeletal maturity, sport practice, and sociocultural characteristics observed at each age level during adolescence as the independent variables. Moreover, for each fitness com-



ponent at age 30 years, extreme groups were selected comprising the two extreme quartiles of the distribution. For these extreme groups, stepwise discriminant analyses were performed with the characteristics observed at each age during adolescence as the discriminating variables (3). All calculations were made using the SAS package (19).

## Results and Discussion

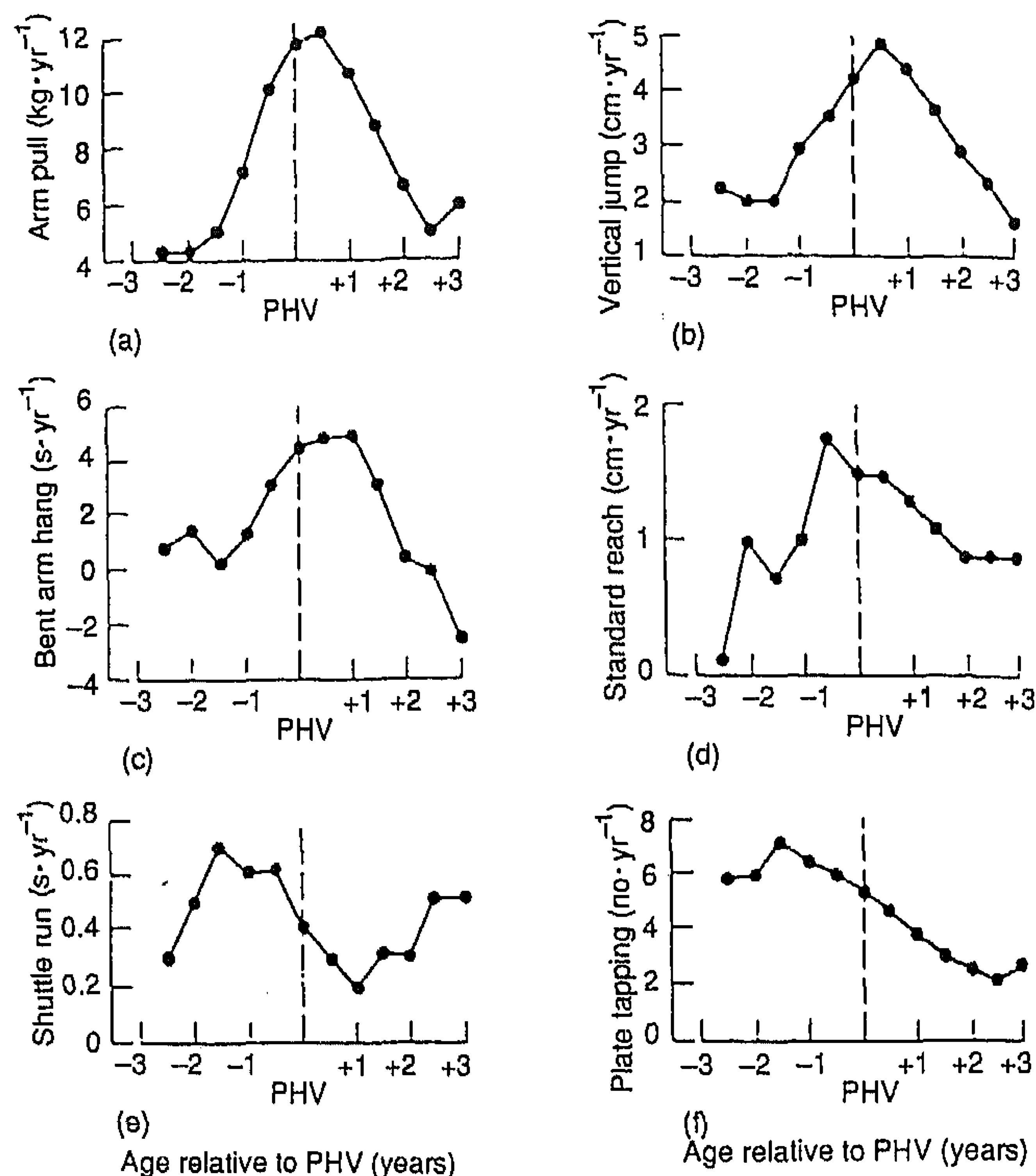
Since all results have been published previously a summary of the data will be given focussing on the main findings.

### Individual growth characteristics of fitness components (7,14)

Half-yearly velocities for six performance tasks in Belgian boys are summarized in Fig. 2. On the average, peak velocities in static strength (arm pull), explosive strength (vertical jump) and muscular endurance (bent arm hang) occur after APHV. The adolescent spurt in these characteristics appears to begin 0.5 years prior to APHV and reach a peak about 0.5 years after APHV. In contrast, maximum velocities in speed tests (shuttle run and plate tapping) and flexibility (sit and reach) occur before APHV. Since the youngest age at first observation in this study is about 12 years the onset of the adolescent growth spurt cannot accurately be defined especially not in characteristics that show a spurt prior to the adolescent spurt in stature. In muscular endurance of the lower trunk muscles (leg lifts) no clear adolescent spurt could be defined. Interestingly none of these gross motor functions show a negative velocity during the years of rapid increase in stature. Such a period of adolescent awkwardness has often been suggested in the general child development literature but is not shown in the longitudinal studies of gross motor performance (4). Adolescent growth spurts in isometric strength of different muscle groups have been demonstrated in other studies of male subjects confirming that the adolescent peak strength development occurs 6 months to 1 year after APHV (5).

Three longitudinal principal components explain more than 99% of the intra-individual variation in height for boys aged 12.5 to 17.5 years (Table 2). For two fitness components three longitudinal principal components also explain most of the variation (94% for arm pull and 91% for vertical jump). Inspection of the component loadings at each age level indicate that the first component presents positive loadings at each age level. The second and third component loadings show a curvilinear association with age, and both have positive and negative loadings. Boys with a high score on component 1 for stature are very tall boys, since their stature is above the 95th percentile of the Belgian reference population throughout the observation period. Conversely, boys with a low score on component 1 are very small as compared to the Belgian reference data. Finally, boys with an average principal component score on component 1 harmonize with the average statures over the entire age range. The first component characterizes the general position of the individual growth curve in respect to the mean growth curve. The second and third components are related to the tempo and timing of the adolescent growth spurt.

Significant correlations ( $P < 0.01$ ) between individual scores on the first three components and other growth parameters estimated from the individual growth curves are summarized in Table 3. Correlations between scores on component 1 and



**Fig. 2** Median velocities of several tests of strength and motor performance aligned on age at peak height velocity (APHV) of Belgian boys: (a) arm pull; (b) vertical jump; (c) bent arm hang; (d) sit and reach; (e) shuttle run; (f) plate tapping. Velocities for the fitness items are plotted as years before and after APHV. Drawn from data reported by Beunen et al. (7). (Reprinted with permission from Beunen and Malina [5]).

**Table 2** Eigenvalues, percent of variation and cumulative percent of variation explained by the three most important principal components for height, arm pull and vertical jump [after Lefevre et al. (14)].

Variables	Components	Eigenvalues	Percentage	Cumulative percentage
Height	1	5.6012	93.35	—
	2	0.2333	3.89	97.24
	3	0.1286	2.14	99.38
Arm pull	1	4.8892	81.49	—
	2	0.423	7.06	85.55
	3	0.2897	4.83	93.38
Vert. jump	1	4.7470	79.12	—
	2	0.4231	7.05	86.17
	3	0.3111	5.18	91.35

adult values are significant. Furthermore, there appears to be a significant relationship between scores on components 2 and 3 and either peak velocity or age at peak velocity for stature. Similar findings are observed for the longitudinal principal components for arm pull and vertical jump.

### Somatic and fitness characteristics of contrasted maturity groups (6, 15)

When early, average and late maturing boys, grouped according to their APHV, are contrasted there are consistent, significant differences during adolescence for body mass, skeletal



**Table 3** Coefficients of correlation ( $p < 0.01$ ) between individual component scores and other estimated parameters for height, arm pull and vertical jump (14).

	Comp. 1	Comp. 2	Comp. 3
Height			
Peak velocity			-.81
Age at peak velocity	-.53	-.82	.49
Adult value	.93		
Arm pull			
Peak velocity	.48	-.33	-.38
Age at peak velocity		-.77	
Adult value	.92		
Vertical jump			
Peak velocity		-.63	-.45
Age at peak velocity		-.42	.71
Adult value	.91	-.47	

lengths and breadths, circumferences, and skinfolds on the trunk. There are no significant differences between the three contrasting maturity groups for skinfolds on the extremities. Interestingly none of the differences in somatic dimensions and ratios among the three contrasting maturity groups are significant at 30 years except those for subscapular skinfold and the trunk/extremity skinfold ratio (Fig. 3). Thus, during adolescence and at adulthood, late maturing boys have a distribution of subcutaneous fat which is associated with lower risk for several adult degenerative diseases.

When comparing the fitness scores of the early, average and late maturing boys in the adolescent period significant differences were found for arm pull (static strength), vertical jump (explosive strength) and plate tapping (speed of limb movement). For plate tapping early maturers perform better than average and late maturers. For vertical jump, early maturers perform better than late maturers, while for arm pull, early and average maturers perform better than late maturers (Fig. 3). At adulthood (30 years) significant differences are seen for plate tapping and bent arm hang (muscular endurance), while for vertical jump the  $F$  value reaches a significance level of  $P < 0.06$ . However, the direction of the significant differences is the opposite for vertical jump and bent arm hang, i.e., average maturers perform at lower levels than late maturers for vertical jump (Fig. 3), while early maturers perform more poorly than the late maturers in bent arm hang. For arm pull the differences between the contrasting maturity groups disappear. For most fitness scores the late maturers thus not only caught up with the average and early maturers, but there were significant differences for explosive strength and muscular endurance in favor of late maturers.

#### *Tracking in fitness scores (2, 3)*

The autocorrelations, as tracking indices, for health- and performance-related fitness components are presented in Table 4. The correlations for the sum of skinfolds, as an indicator of adiposity, varied around 0.50, indicating moderate stability since only 25% of the variance observed at 30 years could be explained by the adiposity observed at younger ages. There was virtually no increase in the autocorrelations with decreasing age interval. Much higher tracking coefficients were found for flexibility (sit and reach). Coefficients for muscular endur-

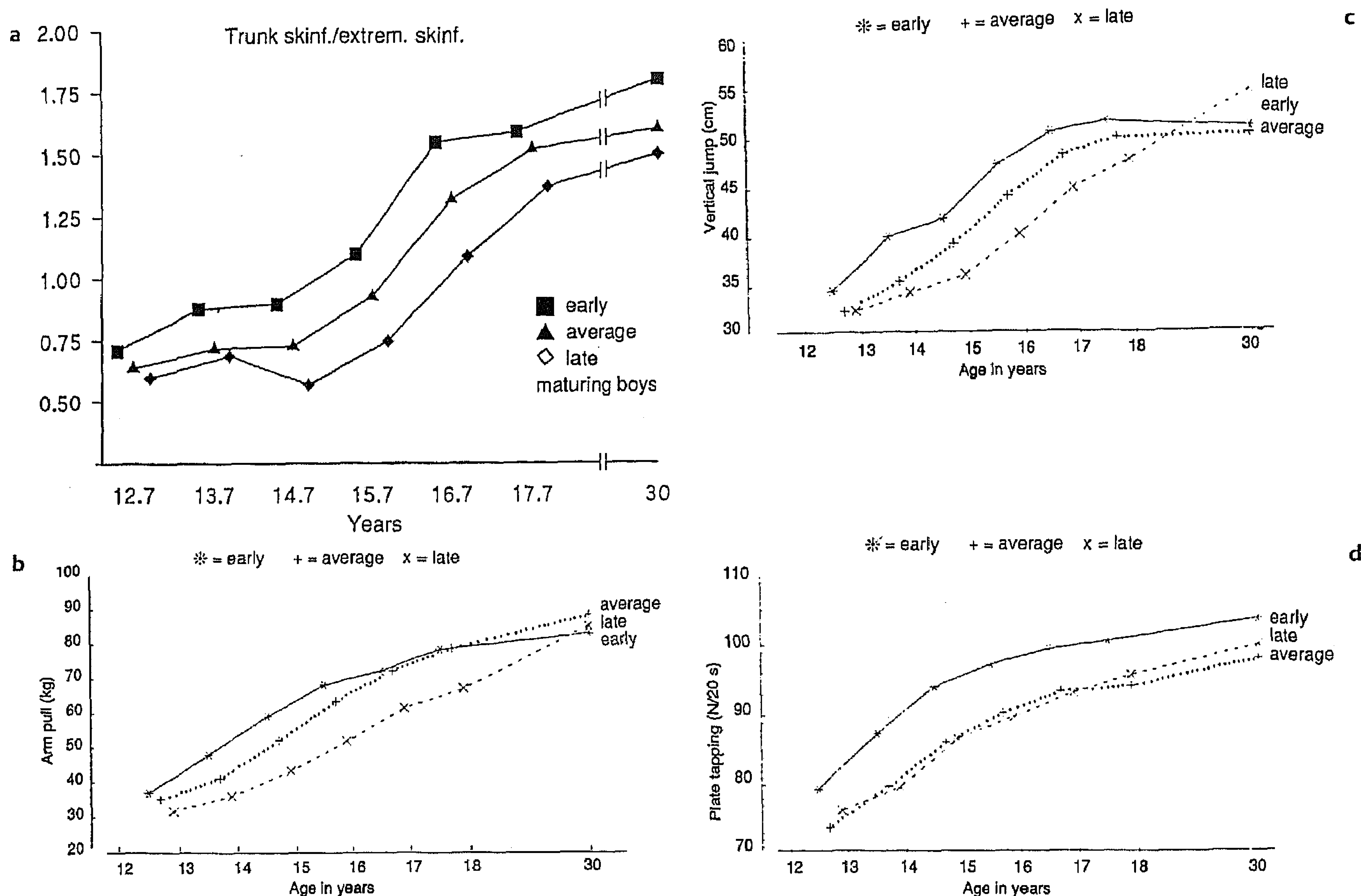
ance and strength in the trunk (leg lifts) and upper body (bent arm hang) were moderate and tended to increase somewhat with decreasing age interval. Tracking for pulse recovery after a step test was low, especially between the ages of 13 and 30 years. For isometric strength the stability coefficient between the ages 13 and 30 was low, but coefficients increased with decreasing age interval resulting in considerable stability between the ages of 18 and 30 years. As for the isometric strength, the stability for explosive strength (vertical jump) increased from moderate values between ages 13 and 30 years to moderately high values between 18 and 30 years. For running speed (shuttle run) and speed of limb movement (plate tapping) autocorrelations increased slightly from about 0.45 between ages 13 and 30 to 0.52–0.54 between ages 18 and 30. Generally, the autocorrelations between ages 13 and 35 were slightly lower than between ages 13 and 30, also the coefficients between ages 18 and 35 were slightly lower than between ages 18 and 30. Between 30 and 35 for most fitness components, however, the tracking indices were moderately high or even high except for pulse recovery after step test, daily physical activity (self-reported by questionnaires) and plate tapping.

The amount of variance of adult fitness levels (age 30 years) explained increased significantly when other characteristics observed during adolescence entered the multiple regressions (Table 5). Only for sum of skinfolds no other somatic or performance characteristics observed during adolescence entered the regressions. For sit and reach at 30 years the explained variance was rather high ( $R$  varies between 0.68 and 0.87). For the ages 18 to 30 the explained variance was moderately high ( $R$  above 0.60) for leg lifts, arm pull, vertical jump, shuttle run and plate tapping. The most important variable that entered the regression was always the same fitness test observed at younger ages, e.g., for arm pull the most important predictor was always arm pull observed at younger ages. Furthermore, somatic dimensions, skeletal maturation, somatotype components, but also other fitness tests, sport practice of the subject and of his mother and sociocultural characteristics of the family entered the regression. The results of the discriminant analyses, for which extreme quartiles of the distribution in fitness scores observed at 30 years were contrasted, confirmed the results reported in Table 5.

#### **Conclusions**

1. The three strength tests (arm pull, vertical jump, bent arm hang) show velocity curves that are quantitatively similar to those of height and body mass. Their adolescent spurts occur after APHV and are more coincident with the body mass spurt. Flexibility (sit and reach) and the two speed tests (plate tapping and shuttle run) appear to reach maximum velocities prior to APHV. Finally, on the average, no decline was observed in any of the fitness characteristics during the period of rapid increase in stature and other body dimensions which leads to the conclusion that, for gross motor function, there is no adolescent awkwardness.
2. In the longitudinal principal component analyses it was shown that this type of analysis has the advantage that the method can be generally applied, implying that characteristics whose growth pattern is not clearly established can be analyzed by this method. Furthermore, it was shown that the longitudinal principal components have biological





**Fig. 3** Average distance curves for early, average and late maturing boys: (a) trunk skinfold/extremity skinfold ratio; (b) arm pull; (c) vertical jump; (d) plate tapping. At the first observation the mean chronological age in early, average and late maturing boys is 12.5, 12.7 and

12.9 years, respectively. The mean chronological ages increase by exactly 1 year at subsequent age levels until 17.5, 17.7 and 17.9 years, respectively. (After Beunen et al. [6] and Lefevre et al. [15]).

meaning. Longitudinal principal component analysis has other applications: e.g., extreme quintiles or quartiles based upon component scores can be contrasted. Furthermore, the individual growth patterns of different somatic dimensions or fitness characteristics or a combination thereof can be combined in one analysis. This permits one to verify if similar growth patterns are present in the somatic or performance characteristics.

3. In adolescent boys early maturers are characterized by larger body mass, skeletal lengths and breadths, circumferences and skinfolds. Furthermore, early maturers outperform average or late maturers for several fitness components during the adolescent period. Contrary to what has been reported in studies in which maturity groups are contrasted and followed until 18 to 20 years (see e.g. 17) no difference was found between early, average and late maturers for body mass observed at age 30 years. Similarly, no differences were found between the contrasting maturity groups for other body dimensions and ratios of body proportion and overweight with the exception of subscapular skinfold and the trunk skinfold/extremity skinfold ratio. Early maturers have relatively more subcutaneous fat on the trunk not only during adolescence but also at adulthood. Thus, early ma-

turation per se in males is associated with a profile of fat distribution that is implicated as a risk factor in several degenerative diseases of adulthood.

Significant differences were also found among the contrasting maturity groups for plate tapping, arm pull and vertical jump. Interestingly, however, the differences in performance between early, average and late maturers disappear or are reversed at adult age (30 years).

4. Health- and performance-related fitness track significantly across childhood and adolescence, but correlations are low to moderate (16). Tracking between age 13 and 30 years was moderately high for flexibility, low to moderate for the other fitness components and low for pulse recovery. Between 18 and 30 years tracking was high for flexibility, moderately high for static and explosive strength, and moderate for the other fitness items except for pulse recovery. Between 30 and 35 years tracking was moderately high or high for most fitness characteristics except for plate tapping, pulse recovery and daily physical activity for which low to moderate tracking was found. The amount of variance of adult fitness explained increased significantly when other characteristics observed during adolescence entered the regression or discriminant functions. This indicated that in

**Table 4** Autocorrelations for health- and performance-related fitness at indicated ages and at age 30 years (left part of the table) and at indicated ages and at age 35 years (right part of the table) (after Beunen et al. 1992, 1996)

Fitness component	Test	Age levels and at age 30 years			Age levels and at age 35 years		
		13	15	18	13	18	30
<i>Health-related fitness</i>							
Adiposity	sum skinfolds	0.47	0.50	0.55	–	–	–
Flexibility	sit and reach	0.68	0.70	0.82	0.64	0.79	0.90
Trunk muscle endurance and strength	leg lifts	0.44	0.55	0.53	0.36	0.46	0.68
Upper body muscle endurance and strength	bent arm hang	0.46	0.49	0.55	0.40	0.55	0.80
Cardiorespiratory function	steptest	0.26	0.36	0.36	0.21	0.26	0.45
	VO <sub>2</sub> peak	–	–	–	–	–	0.57
Daily physical activity	self-report	–	–	–	–	–	0.41
<i>Performance-related fitness</i>							
Isometric strength	arm pull	0.33	0.35	0.66	0.22	0.57	0.73
Explosive strength	vertical jump	0.52	0.49	0.69	0.48	0.69	0.81
Running speed	shuttle run	0.45	0.48	0.52	0.46	0.57	0.78
Speed of limb movement	plate tapping	0.38	0.50	0.54	0.23	0.44	0.42
Balance	flamingo balance	–	–	–	–	–	0.74

**Table 5** Range of multiple correlations and variables entered into the regression equation for health- and performance-related fitness scores at age 30 years and characteristics observed at ages 13, 15 and 18 years (adapted after Beunen et al. 1992)

Fitness component	Tests	Range of multiple correlation and variables entered into the regression equation	
<i>Health-related fitness</i>			
Adiposity	sum skinfolds	.47 – .50	sum of skinfolds
Flexibility	sit and reach	.68 – .87	sit and reach, skeletal maturation, sport practice, sport practice of the mother, arm pull
Trunk muscle endurance	leg lifts	.51 - .63	leg lifts, height, sit and reach, shuttle run, biacromial width, profession of the father
Upper body muscle endurance	bent arm hang	.46 – .59	bent arm hang, body mass, skeletal maturation, arm pull, vertical jump
<i>Cardiorespiratory recuperation</i>	steptest	.36 – .50	pulse recovery, biacromial width, upper arm circumference, sum skinfolds, biepicondylar humerus, arm pull, vertical jump
<i>Performance-related fitness</i>			
Isometric strength	arm pull	.42 – .76	arm pull, skeletal maturation, calf circumference, biepicondylar humerus, ectomorphy, plate tapping, pulse recovery, bent arm hang
Explosive strength	vertical jump	.61 – .77	vertical jump, skeletal maturation, sport practice of mother, degree of urbanisation, pulse recovery, calf circumference
Running speed	shuttle run	.56 – .62	shuttle run, pulse recovery, vertical jump, sport practice of mother, leg lifts
Speed of limb movement	plate tapping	.54 – .63	plate tapping, vertical jump, chronological age, sport practice, arm pull, calf circumference

addition to fitness scores, anthropometric dimensions and skeletal maturation, behavioral characteristics also added significantly to the prediction of adult fitness levels.

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